

INDOOR AIR QUALITY ASSESSMENT

**Burbank Elementary School
266 School Street
Belmont, Massachusetts**



Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
May 2004

Background/Introduction

At the request of the Belmont School Department (BSD), the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at the Burbank Elementary School (BES), 266 School Street, Belmont, Massachusetts. On December 12, 2003, Cory Holmes and Sharon Lee, Environmental Analysts for BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an assessment of the BES. Concerns about indoor air quality related to potential mold growth, particularly in classroom 112, prompted the request. BEHA staff were accompanied by Bob Martin, Director of Facilities, BSD; Patrick McCormack, Health Agent, Belmont Health Department and Richard Cudmore, Chief Custodian, BES.

The BES is a two-story, red brick, building originally constructed in 1931. The school underwent complete interior renovations from 1989 to 1990. Renovations included replacement of the mechanical ventilation system and windows. The school consists of general classrooms, kitchen/ cafeteria, gymnasium, music room, art room, library and office space.

Methods

BEHA staff conducted indoor air quality tests for carbon dioxide, carbon monoxide, temperature and relative humidity with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

The school houses approximately 300 students in kindergarten through grade 4 and has a staff of approximately 25. Tests were taken during normal operations. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were elevated above 800 parts per million parts of air (ppm) in eleven of twenty-nine areas surveyed, indicating inadequate air exchange in a number of areas. Mechanical ventilation is provided by air-handling units (AHUs) located in mechanical rooms and connected to ceiling or wall-mounted air diffusers via ductwork (Picture 1). Return air is drawn into wall or ceiling exhaust vents ducted back to the AHU (Picture 2). Exhaust vents were off or drawing weakly in several areas during the assessment (Table 1). Without the exhaust system operating as designed, normally occurring pollutants cannot be removed allowing them to build up and lead to indoor air quality/comfort complaints.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The initial equipment balancing should have occurred after the installation of the new HVAC systems in 1989-1990. It is recommended that HVAC systems be re-balanced every five years (SMACNA, 1994).

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please consult [Appendix A](#).

Temperature measurements ranged from 67° F to 74° F, which were below the BEHA comfort guidelines in some areas. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants.

In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity measurements in the building ranged from 19 to 37 percent, which were below the BEHA recommended comfort range. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A few areas had water-damaged ceiling tiles, which can indicate leaks from the roof or plumbing system (Table 1). Water-damaged ceiling tiles can provide a source of mold and should be replaced after a water leak is discovered and repaired. BEHA staff identified a wet ceiling tile in room 204, which was reported by BES staff to have a history of roof leaks (Picture 3). Classroom 112 contained several water damaged ceiling tiles (Picture 4). BEHA staff examined conditions above the ceiling plenum and found no signs of leakage, mold growth or associated odors. The water damage appeared to be a result of condensation forming on uninsulated pipes rather than roof or plumbing leaks (Picture 5).

Repeated water damage to porous building materials (e.g., wallboard, ceiling tiles, carpet) can however result in microbial growth. The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur.

BEHA staff conducted a perimeter inspection of the building envelope. A number of potential areas where water can penetrate the building were identified:

- Holes/spaces were observed in exterior brick where mortar is missing/damaged (Pictures 6 and 7).
- Spaces and missing/damaged caulking were observed around window frames (Picture 8).
- Efflorescence was observed on the walls of the cafeteria (Picture 9).

Efflorescence is a characteristic sign of water damage to building materials such as brick or plaster, but it is not mold growth. As moisture penetrates and works its way through mortar and brick, water-soluble compounds dissolve, creating a solution. As the solution moves to the surface of the brick or mortar, water evaporates, leaving behind white, powdery mineral deposits. This condition indicates that water from the exterior has penetrated into the building. In this case, the most likely source of water penetration is infiltration along flashing between building surfaces [(i.e., the metal roof and brick wall) (Picture 10)].

Other sources of moisture and or potential mold growth were observed in the building. Standing water was observed in the ground floor mechanical room (Picture 11). The mechanical room was being used for storage of porous items, including cardboard boxes and paper. A number of items were visibly water damaged. Prolonged moistening of cardboard or paper can result in mold growth in these materials.

Several subterranean pits were located along the perimeter of the building (Picture 12). These pits allow airflow into below grade air intakes for the mechanical ventilation system. Leaves, papers and other debris were observed on the floor of the pits (Picture 13), which can

also provide a source of mold growth. Mold odors and growth can subsequently be entrained into the ventilation system.

Several classrooms contained a number of plants. In several classrooms, plants were found on top of univents. Plants, soil and drip pans can serve as sources of mold growth, and thus should be properly maintained. Plants should have drip pans to prevent wetting and subsequent mold colonization of window frames. Plants should also be located away from univents and ventilation sources to prevent aerosolization of dirt, pollen or mold.

Other Concerns

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants; however, the pollutant produced is dependent on the material combusted. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM_{2.5}) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM_{2.5}. Outdoor carbon monoxide concentrations were non-detect or ND (Table 1). Carbon monoxide levels measured in the school were also ND.

Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level

over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions of reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000).

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. *Carbon monoxide should not be present in a typical, indoor environment.* If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels.

The NAAQS originally established exposure limits for particulate matter with a diameter of 10 μm or less (PM₁₀). According to the NAAQS, PM₁₀ levels should not exceed 150 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) in a 24-hour average. This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM_{2.5} standard requires outdoor air particulate levels be maintained below 65 $\mu\text{g}/\text{m}^3$ over a 24-hour

average. Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at $2 \mu\text{g}/\text{m}^3$ (Table 1). PM2.5 levels measured indoors ranged from 3 to $13 \mu\text{g}/\text{m}^3$. Although PM2.5 measurements were above background, they were below the NAAQS of $65 \mu\text{g}/\text{m}^3$. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were non-detect (ND) (Table 1). Indoor TVOC measurements throughout the building were also ND.

Please note, that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted

by the use TVOC containing products (i.e., the concentration of TVOCs within a classroom when the products are actually in use). While no TVOC levels measured exceeded background levels, materials containing VOCs were present in the school. Several classrooms contained dry erase boards and dry erase markers. Materials such as dry erase markers and dry erase board cleaners may contain volatile organic compounds (VOCs), (e.g., methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Cleaning products were found in unlocked cabinets below sinks and on countertops in a number of classrooms (Picture 14). Cleaning products also contain chemicals that can be irritating to the eyes, nose and throat and should be kept out of reach of students.

Unlabeled/poorly labeled spray bottles were also noted. Products should be kept in their original containers, or should be clearly labeled as to their contents, for identification purposes in the event of an emergency.

A number of exhaust/return vents were noted with accumulated dust. If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize accumulated dust particles. Also of note was the amount of materials stored in some classrooms. Items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items, (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up. Dust can be irritating to eyes, nose and respiratory tract.

Finally, spaces were noted around the boiler room door, where light from the room was evident. These spaces can serve as a means of egress for odors, fumes, dusts and vapors from the boiler room into adjacent areas.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Remove water damaged porous materials from mechanical room and refrain from using as storage space. Disinfect any areas of microbial growth with a one in ten bleach in water solution; wipe clean surfaces with soap and water after disinfection. Ensure HVAC system is deactivated prior to any cleaning activities.
2. Contact a building engineer and/or building envelope specialist to examine means to prevent water infiltration into lower level areas.
3. Consult “Mold Remediation in Schools and Commercial Buildings” published by the US EPA (US EPA, 2001) for further information on mold and/or mold clean up. Copies of this document are available from the US EPA at:
http://www.epa.gov/iaq/molds/mold_remediation.html.
4. Operate both supply and exhaust ventilation continuously during periods of school occupancy, independent of classroom thermostat control to maximize air exchange. Consult the school’s heating, ventilation and air conditioning (HVAC) engineer concerning an increase in the introduction of outside air.
5. Ventilation industrial standards recommend that mechanical ventilation systems be balanced every five years (SMACNA, 1994).
6. Inspect exhaust/return system for proper function. Make repairs/adjustments as necessary.
7. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when

the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

8. Replace water damaged ceiling tiles. Insulate pipes above ceiling tiles to prevent condensation and further water damage.
9. Seal holes/breaches in the building envelope to prevent water penetration and pests. Consider having brick re-pointed.
10. Work with a building contractor to identify and repair leaks around flashing (Picture 10).
11. Remove leaves and debris from subterranean pits seasonally.
12. Remove plants from the vicinity of univents. Ensure plants are equipped with drip pans. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary.
13. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
14. Clean exhaust/return vents periodically to prevent excessive dust build-up.
15. Install door sweep and/or weather stripping around boiler room door to prevent the migration of odors into adjacent areas.
16. Store cleaning products properly and out of reach of students. Ensure spray bottles are properly labeled in case of emergency.

17. Consider adopting the US EPA document, “Tools for Schools” to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at:
<http://www.epa.gov/iaq/schools/index.html>.
18. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH’s website at <http://www.state.ma.us/dph/beha/iaq/iaqhome.htm>.

References

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Picture 1



Wall-Mounted Supply Vents

Picture 2



Wall-Mounted Exhaust/Return Vent

Picture 3



Water Damaged Ceiling Tile in Room 204 (Wet During Assessment on 12/12/2003)

Picture 4



Water Damaged Ceiling Tiles in Classroom 112

Picture 5



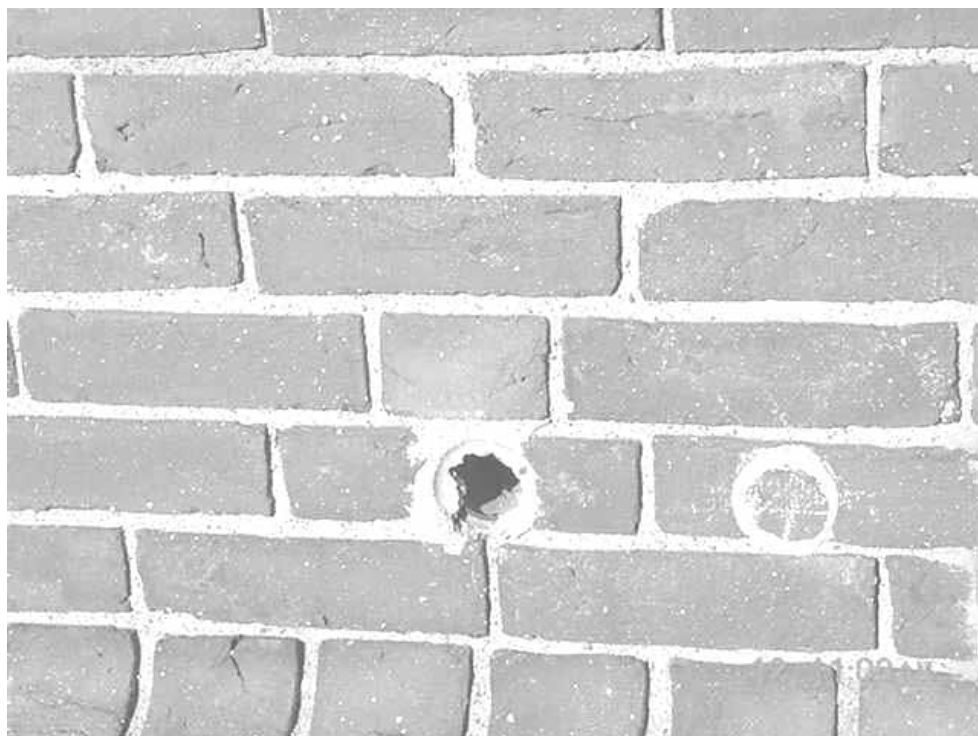
Uninsulated Pipe above Water Damaged Ceiling Tiles in Picture 4

Picture 6



Missing/Damaged Mortar around Brick

Picture 7



Open Hole in Exterior Brick

Picture 8



Missing/Damaged Caulking around Window Frame

Picture 9



Efflorescence on Cafeteria Wall Indicating Water Penetration

Picture 10



Building Interface, Area of Potential Water Infiltration around Flashing

Picture 11



Standing Water in Mechanical Room, Note Storage of Materials

Picture 12



Subterranean Pit for Air Intake

Picture 13



Leaves, Plants and Other Debris in Subterranean Intake Pit

Picture 14



Spray Cleaning Products in Unlocked Cabinet and on Countertop in Classroom

Burbank Elementary School
266 School Street, Belmont, MA

Table 1

Indoor Air Results
December 12, 2003

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background (outdoors)	46	22	329	ND	ND	2	-	-	-	-	NW winds 20 mph, clear skies, sunshine
112	67	37	659	ND	ND	8	18	Y	Y	Y	WD CTs-condensation from uninsulated pipes
109 Guidance	71	26	476	ND	ND	8	0				PF, cleaning products, plants
Crawl Space Mechanical Room											1-2 inches of standing water, WD boxes/papers, mechanical room used for storage
204	72	27	953	ND	ND	12	1	Y	Y	Y	DO, wet CT, history of roof leaks, unlabeled spray botte,
203	72	25	1069	ND	ND	9	17	Y	Y	Y	DO, cleaning products
102 Music	71	29	1076	ND	ND	6	20	Y	Y	Y	Dusty vents

ppm = parts per million parts of air
µg/m3 = microgram per cubic meter
CT = ceiling tile
AD = air deodorizer
AP = air purifier

CD = chalk dust
DEM = dry erase marker
DO = door open
ND = non detect
PC = photocopier

PF = personal fan
TB = tennis balls
UF = upholstered furniture
UV = univent
WD = water damage

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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									Supply	Exhaust	
101 Gym	73	28	710	ND	ND	3	1	N	Y	Y	
106	68	26	584	ND	ND	4	0	Y	Y	Y	Exhaust in separate room, pencil shavings, dry sink, abandoned vent fan
Art	69	28	787	ND	ND	4	22	Y	Y	Y	Dusty vents
Girls Restroom									Y	Y	Dry drain traps
Parking Lot Stairwell											WD paint bubbling
214	72	23	910	ND	ND		21	Y	Y	Y	Occupants gone 5 min, WD CTs
216	69	19	594	ND	ND	5	0	Y	Y	Y	Exhaust weak

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									Supply	Exhaust	
209	72	20	713	ND	ND	5	5	Y	Y	Y	
215	72	21	592	ND	ND	4	0	Y	Y	Y	Exhaust weak, DEM, PF, CTs
213	72	25	769	ND	ND	8	0		Y	Y	Exhaust weak, PF, chalk dust, cleaning products
211	71	26	745	ND	ND	12	8	Y	Y	Y	Exhaust weak, 4 CTs, DO, chalk dust, plants
210	71	25	549	ND	ND	13	0	Y	Y	Y	Food use/storage, chalk dust, aquarium, clutter/dust, cleaning products, unlabeled spray products
Hallway to third floor											Water damaged ceiling plaster
205	74	22	753	ND	ND	8	1	Y	Y	Y	WD-paint, risograph, photocopier

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									Supply	Exhaust	
Main Office	74	21	718	ND	ND	7	1	Y	Y	Y	
Library	72	21	759	ND	ND	6	2		Y	Y	WD window, exhaust weak
209	72	23	980	ND	ND	9	19	Y	Y	Y	Dusty vents, cleaning products, spaces sink countertop
Cafeteria	70	31	473	ND	ND	8	100	Y	Y	Y	DO
202	70	30	1055	ND	ND	8	0	Y	Y	Y	Exhaust off, cleaning products, plants
201	71	31	1580	ND	ND	8	25	Y	Y	Y	Feather duster, plants, PF
303	72	31	904	ND	ND	8	0	Y	Y	Y	DO, ceiling fans, exhaust vent over hallway door

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305	73	25	722	ND	ND	8	1	Y	Y	Y	
306	74	26	683	ND	ND	8	0	Y	Y	Y	Chalk dust, cleaning products, accumulated items, DEM, exhaust off, DO
303	72	29	906	ND	ND	8	1	Y	Y	Y	23 occupants gone 40 minutes, exhaust off
304	72	29	1198	ND	ND	8	0	Y	Y	Y	Dust accumulation on fan, potting soil, exhaust off, PF, cleaning products, chalk dust, pets, aquarium
Boiler Room				ND	ND						Water damaged wood pallets, recommend door sweep under door
307	74	28	1114	ND	ND	8	19	Y	Y	Y	Dusty vents, unlabeled spray bottles
308	73	27	709	ND	ND	7	0	Y	Y	Y	Exhaust off/weak, DEM, chalk dust, plants, accumulated items, cleaning products

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